Micron Optics, Inc.

Faster, More Accurate Filters for All-Optical Networks

The increased need for speed and precision in a variety of communication networks has spurred the quest to develop high-speed, high-capacity, packet-switched, all-optical fiber networks. Networks face bottlenecks, among them the slowness of electronic switches. In a project that started in 1994, Micron Optics, Inc., a small company from Atlanta, GA, was awarded funds by the Advanced Technology Program (ATP) to develop the technology to increase the speed and accuracy of fiber Fabry-Perot tunable filters (FFP-TF) using ferroelectric liquid crystals. Although Micron Optics was unable to accomplish this goal, the company was able to miniaturize the FFP-TF, and this improved device is currently being used in the mechanical sensing, optical performance, and test equipment markets.

COMPOSITE PERFORMANCE SCORE

(based on a four star rating)

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Research and data for Status Report 93-01-0027 were collected during October-December 2001.

Telecommunication Networks Require High-Speed Capacity

Advances in telecommunications occur at a rapid pace, but technological advances are sometimes uneven. This was the case when the use of fiber optics for transporting telecommunication signals began to expand rapidly within the industry in the early 1990s.

Increased bandwidth demands could not be met with electronic networks.

Prior to the start of this ATP project, millions of miles of fiber that carried long-range and local communications were already in place in the United States. However, there was a bottleneck problem in the electronic systems that were used to detect and switch signals at both ends of the fibers. Furthermore, increased bandwidth demands could not be met with electronic networks. It was anticipated that the use of all-optical networks would solve this problem. Networks were increasingly using a technique called wavelength division multiplexing (WDM), which uses optical rather than electronic systems. WDM involves using multiple laser wavelengths to carry many signals simultaneously simultaneously. In the end, a machine is used that can translate the light back into binary signals if necessary.

Century-Old Technology Updated for Optical-Fiber Networks

As fiber-optic applications technology continued to develop, it became clear that the direct optical processing of signals without conversion to electronic signals was required to sustain the speed necessary to keep up with the volume that was building in these systems. A fiber Fabry-Perot (FFP) interferometric filter is one component that can handle such an application.

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The Fabry-Perot was first described by C. Fabry and A. Perot in 1897. Fabry-Perot filters are constructed of bulk lenses, mirrors, and beam optics along with geared positioning stages. For more than 100 years, designs based on these original optical configurations have provided the highest known optical wavelength

A miniaturized Fabry-Perot tunable filter (FFP-TF).

resolution. Other filter and tunable laser technologies offered the speed, but lacked either the tuning range or the resolution that was needed. Micron Optics added a single segment of fiber within the original Fabry-Perot device and patented the fiber Fabry-Perot tunable filter (FFP-TF). The FFP-TF is a simpler design, since it does not require complex optics and lenses; yet FFP-TFs are more robust and field-worthy than traditional Fabry-Perot interferometers. Since the early 1990s, Micron Optics has been the only supplier in the world of FFP components, including optical filters used as switches in optical-fiber networks.

However, as progress was made in telecommunication networks and their usage grew, it became apparent that the packet-switching, all-optical networks planned for the future would require far more capability than what Micron Optics could produce in the early 1990s. The electromechanical (piezoelectric)-tuned FFP filters commercially available in the early 1990s had wide wavelength-tuning ranges, but their tuning speed was limited to the 1- to 10-millisecond range. This was 1,000 times too slow for packet-switching. [(1)] In addition, these filters were limited in capacity to between 50 and 100 channels, whereas a capacity approaching 1,000 channels was needed.

Each filter cost thousands of dollars; however, widespread use could only be achieved if the cost was approximately $100. Therefore, to keep up with the capability of optical networks, it would be necessary to improve the tuning speed by a factor of 1,000, channel capacity by a factor of 10, and cost by a factor of 10.

Micron Optics Designs a Faster Fiber Fabry-Perot Tunable Filter

Micron Optics envisioned a highly optimized version of its FFP-TF that would be faster and could reach more channels by replacing the present piezoelectric-tuning mechanism with a ferroelectric liquid crystal (FLC) cavity capable of tuning the filter to the desired wavelength without requiring moving parts. The company sought to develop an FFP-TF with quicker tuning speeds and channel capacities approaching 1,000, (reaching a finesse, i.e., measure of sharpness, approaching 2,000) while costing only several hundred dollars per filter. This was an ambitious endeavor because the required improvement in performance was significant. Micron Optics wanted to develop an FFP-TF that used FLCs to tune the path length electro-optically in hopes that it would achieve packet-switching speeds that were three orders of magnitude faster than the piezoelectric device that was used for channel switching.

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With $1.895 million in co-funding from ATP, Micron Optics teamed with subcontractors, IBM and University of Colorado, in a three-year research program to achieve these performance and cost goals. The University of Colorado focused on the FLCs, and IBM provided a testbed for evaluating the new filters. The research program centered on evaluating the following:

- High-performance FFP-TFs that included high finesse, low-insertion loss, dual-band functionality, device miniaturization, and stable thermal and mechanical characteristics

- High-speed FLC-based FFP-TFs

1. Packet-switching is a method whereby messages are divided into packets before they are sent. Each packet is then transmitted individually and can even follow different routes to its destination. Once all the packets forming a message arrive at the destination, they are recompiled into the original message.

Through its collaboration with ATP, the company was able to miniaturize the FFP-TFs. Micron Optics developed a prototype that demonstrated high-speed performance and low-cost fabrication. The new fabrication technique was an improvement over Micron Optics' previous technique, which required constant realignment. These improved FFP-TFs had higher finesses (>2,000), lower loss, lower mass and smaller size, good thermal and mechanical stability, and the potential for low-cost, high-volume production.

Unfortunately, research into the high-speed FFP filters using FLCs resulted in minimal success. While these FFPs provided moderate improvements in wavelength tuning range, switching time, finesse, and total insertion loss, the device fell short of Micron Optics' originally proposed goals of quicker tuning speeds and increased channel capacities.

With ATP support for research and development, Micron Optics responded to the needs of the market at the right time by decreasing the cost of FFP-TF manufacturing by 99 percent.

For these reasons, at the conclusion of the ATP project in 1996, the company decided to focus its future development efforts on improving FFP-TFs that used piezoelectric-tuning mechanisms, and they spent no more effort utilizing FLCs.

Strategic Alliances Result from ATP Funding

Advances made during its ATP project allowed Micron Optics to form pivotal collaborative alliances in the post-project period with equipment and system developers for further development of optical filter technologies. The company formed a joint effort with Photo Kinetics, Inc., to develop optical channel analyzers for WDM applications based on high-performance FFP-TFs.

Further, Micron Optics worked with the Massachusetts Institute of Technology Lincoln Labs on optical coherence tomography, an alternative to ultrasound imaging that can be used in sensor networks.

Conclusion

With ATP support for research and development, Micron Optics responded to the needs of the market at the right time by decreasing the cost of FFP-TF manufacturing by 99 percent.

The prototypes built by Micron Optics helped the firm strengthen its position in the telecommunications market as well as expanding into new markets. Shortly after the project ended, the company began introducing its FFP-TF technology into the mechanical-sensing market through prototype-based marketing in early 1997. More recently, it has expanded into the optical performance and test equipment areas.

PROJECT HIGHLIGHTS
Micron Optics, Inc.

Project Title: Faster, More Accurate Filters for All-Optical Networks (Fiber Fabry-Perot Tunable Filters for All-Optical Networks)

Project: To combine FLCs as the tuning element in fiber Fabry-Perot optical filters suitable for a high-speed, high-capacity, packet-switched, all-optical fiber communications network with switching speeds of 1 to 10 microseconds and capacities approaching 1,000 channels.

Duration: 1/1/1994-12/31/1996
ATP Number: 93-01-0027

Funding (in thousands):

ATP Final Cost	$1,895	58%
Participant Final Cost	1,354	42%
Total	$3,249	

Accomplishments: Through ATP's funding support for research and development, Micron Optics developed a prototype of a tunable high-speed FFP, which was a significant technical development. Moreover, the company experienced a 100-percent increase in sales, a 50-percent increase in research and development funding, and a sevenfold increase in the number of its employees. They gave several presentations and published 25 articles on its project-related research.

Micron Optics received the following five patents for technologies resulting from this successful ATP project:

- "Temperature compensated fiber Fabry-Perot filters"
  (No. 5,509,093: filed August 9, 1994, granted April 16, 1996)
- "Temperature compensated fiber Fabry-Perot filters"
  (No. 5,563,973: filed May 30, 1995, granted October 8, 1996)
- "Reference system for optical devices including optical scanners and spectrum analyzers"
  (No. 5,838,437: filed April 9, 1997, granted November 17, 1998)
- "Fabry Perot/fiber Bragg grating multi-wavelength reference"
  (No. 5,892,582: filed July 21, 1997, granted April 6, 1999)
- Temperature compensated fiber Bragg gratings”
  (No. 6,044,189: filled December 3, 1997, granted March 28, 2000
- "Fabry-Perot Fiber Bragg Grating Multiwavelength Reference"
  (No. 6,115,122: filed April 5, 1999, granted September 5, 2000)
- "Fabry-Perot/Fiber Bragg Grating Multiwavelength Reference"
  (No. 6,327,036: filed September 5, 2000, granted December 4, 2001)

Commercialization Status: Although Micron Optics did not develop an FFP-TF using FLCs, by 1995 the company had improved its original FFP-TF by developing a prototype that incorporated the results of its ATP-funded project. These results yielded advances over the earlier filter in terms of high-speed performance and low-cost fabrication. The prototype has since been commercialized, and companies in multiple industries use the technology in various components.

Outlook: Micron Optics was able to improve its FFP-TFs; however, the outlook for FLC-based FFPs is poor because the company was unable to meet its technical goals. Since the conclusion of the project, the company has redirected its attention on continuing to improve piezoelectric transducer-based FFPs.

Composite Performance Score: * *

Number of Employees: 10 employees at project start, 74 employees upon completion of status report

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Subcontractors:
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Research and data for Status Report 93-01-0027 were collected during October-December 2001.